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An Indoor Guidance System for the Blind using Fluorescent Lights
- Relationship between Receiving Signal and Walking Speed -

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Abstract—The aim of this study is to demonstrate the relationship between the user's walking speed and the data transmission speed in an indoor guidance system using fluorescent lights and a wireless LAN. A simulation formula is used to give out the direct relationship between the parameters. We simulated four angles (30°-90°) between the sensor and the horizontal direction. Three different walking speeds and four different data transmission speeds (1200bps-9600bps) were applied at all angles. Also we designed a series of experiments to validate the formula.

Index Terms— Fluorescent light, indoor guidance system, data transmission speed, simulation formula, wireless LAN

I. INTRODUCTION

FLUORESCENT LIGHT has been regarded as a potential medium for an indoor guidance system [1]-[2]. In 1996, Leeb suggested such an application but little or no practical progress has been forthcoming from him. In 2004, Makino et al. proposed a stand alone indoor guidance system, which used fluorescent light, wireless LAN, control equipment [3]. Fig.1. shows the configuration of the developed system. The system was divided into two sections. In the upper section, transmission data are output through fluorescent lights. In the lower section a user is able to receive guidance information via a personal computer (pc). The data are then updated by the guidance server.

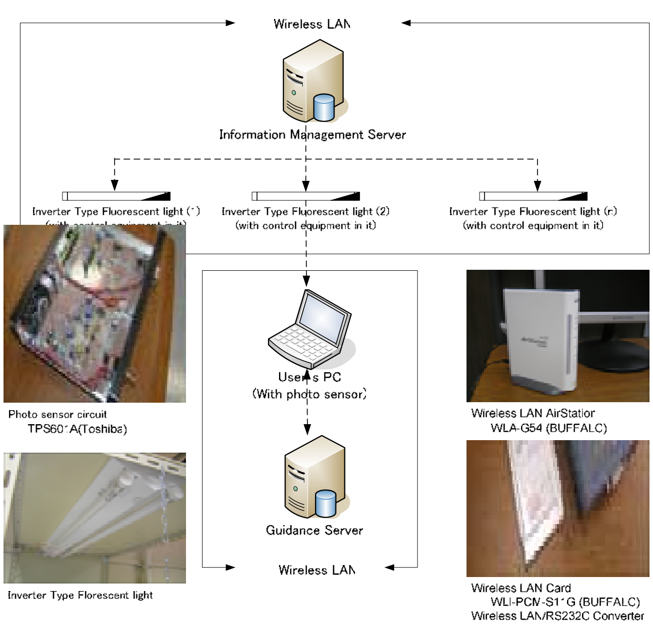

Fig.1. System configuration

In this system, when the user walks under the fluorescent lights, the speed of the user can be variable, either fast or slow, or even both. Here is a problem: can the actual users walking at different speeds catch complete data from fluorescent light?

Here we present a theoretical formula to simulate the condition and then conduct an experiment to validate this formula.

Clearly, changing the angle will change the range over which the sensor can receive a signal. For this reason, we add an angle parameter to the formula to provide a clearer indication of the interactions between the components.

II. METHODS

A Simulation Formula

Fig.2. shows the experimental condition of the system.

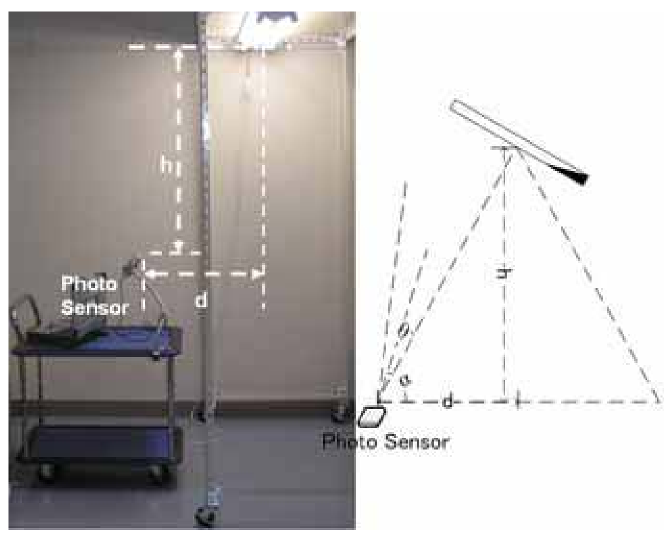

Fig.2. Experimental Condition

Meanings of some parameters are shown in Table I.

Formula (1) shows the relationship between the user walking speed and data transmission speed, the formula also includes the angles between the sensor and horizontal direction.

$$R=\begin{cases}1, v\le \dfrac{h\cdot Tr\cdot \tan(90-\alpha+No\cdot\theta)}{20n}\\[2ex] 0, v> \dfrac{h\cdot Tr\cdot \tan(90-\alpha+No\cdot\theta)}{20n}\end{cases} \tag{1}$$

TABLE I
EXPERIMENT PARAMETER

Parameter	Meaning	Data
h	Distance between the sensor and the fluorescent light in the vertical direction	1.1m
α	The angle between the sensor and the horizontal direction	–––
No	The number of the sensors that we hold together (for getting a longer range.)	1-4
θ	The receiving angle of the sensor	10°
d	The maximum distance that the sensor can catch the light signals	–––
Tr	Data transmission speed	1200-9600bps
v	The user's walking speed	0.5 -3 m/s
n	The length of the data that the sensor can get with 100%	20-1k bytes
R	Result of the experiment: whether the user can get a completer set of signals	0,1

B Formula Verification-Measuring the Range

For getting longer range, in this experiment, we have used 2 sensors and we join them together in the circuit.

The experiment consists of three parts: (1) to measure the maximum distance; and (2) to change the variable parameter to verify the formula when the angle between the sensor and horizontal is 90°; (3) to change other angles to verify the formula. In this indoor guidance system, users are supposed to catch information by walking under fluorescent light. In our experiment, the walking speeds of users are roughly divided into 3 levels: normal, slow, and fast (0.5, 1.3, 3 m/s).

The range in which the sensor can get the light signals is shown in Fig.3. Here we give out 3 methods.

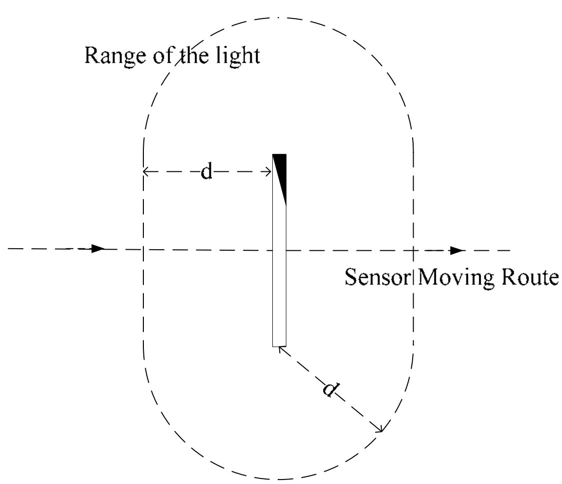

Fig.3. Range Shape that the sensor can get the signals.

1) The first method: We use a simple geometry relation to calculate a theoretical range.

We use the formula as is shown in (2), which is a very important step to get the final formula.

$$d = h \cdot \tan(90 - \alpha + No \cdot \theta) \quad (2)$$

2) The second method: Here we use oscilloscope, protractor, and photo sensor to get a voltage-distance diagram. The situation is shown in Fig.4.

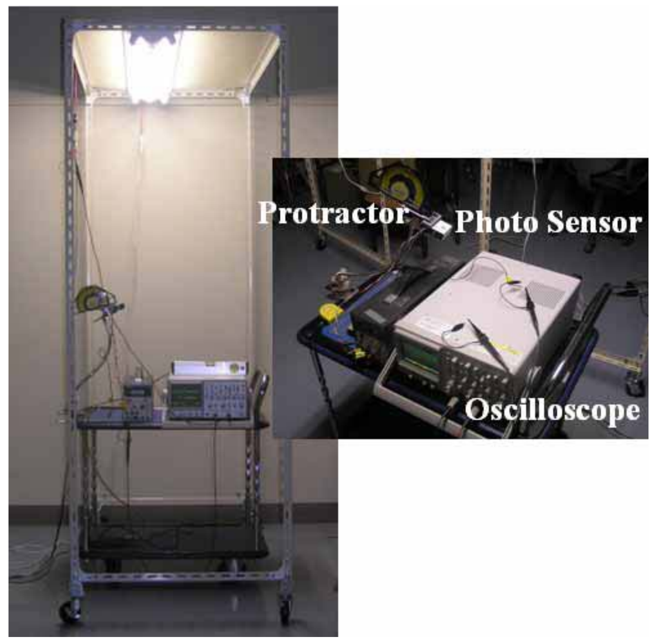

Fig. 4 Range Measuring Experiment. The protractor is on the top of the photo sensor for measuring the angle between the sensor and the horizontal direction. The oscilloscope is used to measure the output voltage of the photo sensor.

3) The third method: Here we connect the sensor with a lap top pc to display the signals received by the sensor.

TABLE Π
DATA CONDITION

Symbol	Meaning
C1	The sensor cannot get any signals
C2	The sensor can get some light signals, but on the display there is no correct data
C3	The sensor can get some part of the data, but not complete data
C4	We can get complete data on the display.

After the fluorescent light begin to send out data signals, we just move the sensor under the fluorescent lights, from far to near, and see what signals we can get, Table Π shows the data condition.

Using the 3rd method, we can also get a condition-distance diagram. After compare with the results of the 3 methods, we can get a coordinate range during which the sensor can get signals clearly.

C Formula Verification-Changing the parameter

The most important parameters in the experiment is v, Tr, α, and Ns. For getting a longer range, we make a circuit with 2 photo sensors, as is shown in Fig.5.

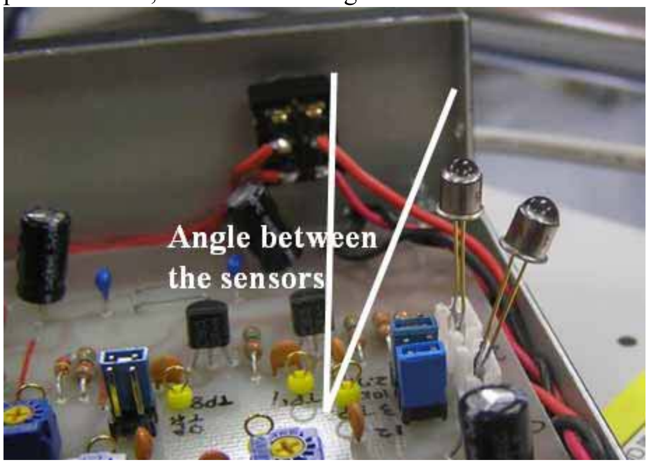

Fig.5. Circuit with 2 photo sensors, we make the angle between the sensors 20°, which means the angle of the whole sensor is 40°

And the parameters we change in the experiment is shown in Table Ⅲ. We set v 0.5m/s, 1.3m/s, and 3m/s.

TABLE Ⅲ
EXPERIMENT PARAMETER

Parameter	Data
α	90°/70°/50°/30°
Tr	1200bps/ 2400bps/ 4800bps/ 9600bps
v	0.5 m/s/ 1.3 m/s/ 3m/s
n	20-1k bytes

The human's normal walking speed is 1.3m/s, if he walks faster, we set the speed 3m/s, and if the user walks slower, we set the speed 0.5m/s.

Ⅲ. Results

A The Range of the sensor

As there are so many conditions, here we only give out the comparison of the results when a=90°.

1) The Result using the first method: We use (2) to calculate the biggest distance, and we got the result 0.40m.

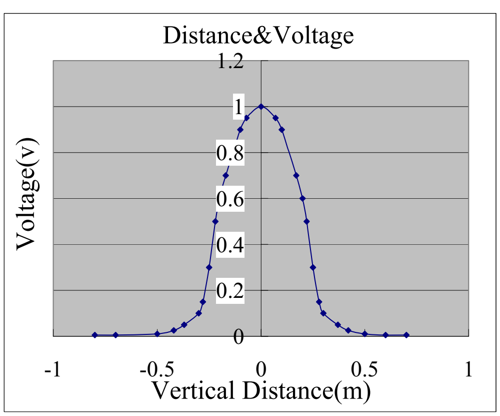

Fig.6. Distance-Voltage Diagram

2) The Result using the second method: We move the sensor straightly under the fluorescent lights, and we record the waveform of the oscilloscope, we got the diagram as is shown in Fig.6.

3) The Result using the third method:

The Distance-Condition diagram is shown in Fig.7. Here I changed the condition C1, C2, C3, C4 for 0,1,2,3.

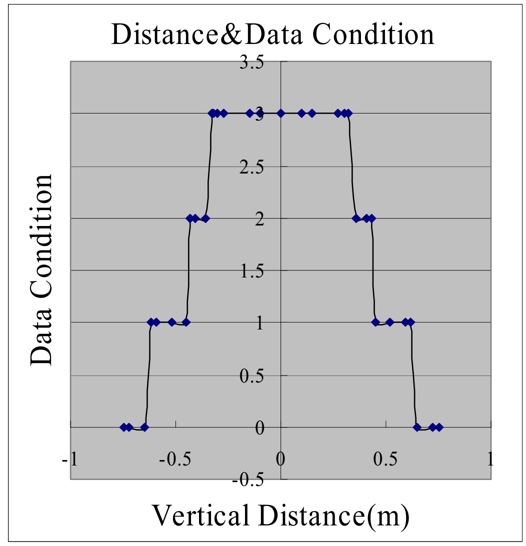

Fig.7. Distance-Condition Diagram

On the basis of the 3 results, we can see that the longest distance in the condition of "α=90°" is about 0.40m. The results of other conditions are shown in Table VI.

TABLE VI
LONGEST DISTANCE

Parameter	Data			
α	90°	70°	50°	30°
d	0.40m	0.92m	1.91m	6.23m*

For a=30°, we only give out the theoretical result.

B Results of the Formula Verification

Now we change the parameters and do some further experiments. We move the sensor under the fluorescent lights. And we connect a lap top pc with the sensor. Then use a data receiving program to output the audio of what we get. (The audio occurs only if the sensor gets the whole text which we

TABLE V
EXPERIMENT RESULT (1)

Parameter	Data	Parameter	Data
Tr	9600bps	α	90°
No	2	d	0.40m
Experiment Result(Experimental result/Theoretical result):			
Walking Speed	0.5m/s	1.3m/s	3m/s
Short data(50bytes)	o/o	o/o	o/o
Normal data(144bytes)	o/o	o/o	—/—
Long data(200bytes)	o/o	o/—	—/—

send out using wireless LAN and fluorescent lights.)

Here we only give out the result when *Tr* = 9600bps.

At the beginning, we set the angle α=90°. The result is shown in Table V.

In the table, symbol "○" means that the sensor can get complete information. Symbol "––" means that the sensor can not get complete information.

When the user moves the sensor with a speed of 1.3m/s, we can use (2) to calculate the data length, which is called "normal data" in this table.

Please note that when the user walks with 1.3m/s with the transmitted data length 200bytes. The experimental result is different from the theoretical result.

That is because that when we build up the formula, we think that the sensor must get 2 times whole data to be sure that we can completely get the data from head to end at least 1 time.

So in some condition, even when the user walks with normal speed, and the fluorescent lights send out a long data, the sensor can also get complete data.

The result with other angles between the sensor and the horizontal is shown in Table VI, Table VII, and Table VIII.

TABLE VI
EXPERIMENT RESULT (2)

Parameter	Data	Parameter	Data
Tr	9600bps	α	70°
No	2	*d*	0.92m

Experiment Result(Experimental result/Theoretical result):

Walking Speed	0.5m/s	1.3m/s	3m/s
Short data(200bytes)	○/○	○/○	○/○
Normal data(340bytes)	○/○	○/○	––/––
Long data(500bytes)	○/○	––/––	––/––

TABLE VII
EXPERIMENT RESULT (3)

Parameter	Data	Parameter	Data
Tr	9600bps	α	50°
No	2	*d*	1.91m

Experiment Result(Experimental result/Theoretical result):

Walking Speed	0.5m/s	1.3m/s	3m/s
Short data(500bytes)	○/○	○/○	––/––
Normal data(705bytes)	○/○	○/○	––/––
Long data(1kbytes)	○/○	○/––	––/––

Based on the experimental results, now we give out an explanation of the results using (1) and the experimental data.

We just give out the results when the situation is the same as the situation of TABLE V.

When the sensor's moving speed is 1.3m/s, and we send out the data with the length 144bytes. First we use (1) to calculate the right part.

As is shown below:

$$\frac{h\cdot Tr\cdot\tan(90-\alpha+No\cdot\theta)}{20n}=$$

$$\frac{1.1\cdot 9600\cdot\tan(90-90+2\cdot 10)}{20\cdot 144}m/s=1.33m/s \qquad (3)$$

So the theoretical result is: when the sensor's moving speed is smaller than 1.33m/s as we got in (3), we can get the complete data.

The experimental result is: when the user walks under the fluorescent light with the normal speed of 1.3m/s, we got complete data from the sensor. That means the theoretical result is equal with the experimental result in this condition.

TABLE VIII
EXPERIMENT RESULT (4)

Parameter	Data	Parameter	Data
Tr	9600bps	α	30°
No	2	*d*	6.23m*

Experiment Result(Theoretical result):

Walking Speed	0.5m/s	1.3m/s	3m/s
Short data(1kbytes)	○	○	––
Normal data(2kbytes)	○	○	––
Long data(3kbytes)	○	––	––

Following an evaluation of the other experimental results we conclude that if we remove the error factors involved in measuring the longest distance, then the empirical result conforms to the theoretical result.

The relation between walking speed and data length at four levels of transmission rate in the given fluorescent communication system was successfully examined and confirmed by our theoretical simulation formula and the following experiment. This theoretical formula proposed in this paper will be useful to design a more reliable and sensitive photo sensor and accordingly a communication system using fluorescent light for practical use.

ACKNOWLEDGMENT

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